AGS OPERATIONS PROCEDURES MANUAL

8.11.4 PROCEDURE FOR LH_2 TARGET EMERGENCY

Text pages 1 through 2

Attachment

Hand Processed Changes

HPC No.	Date	Page Nos.	Initials

Revision No. ___ Approved:

Gerard T. Trowbridge
AGS Department Chairman

11/14/90
Date

8.11.4 PROCEDURE FOR LH_2 TARGET EMERGENCY

1 Purpose

The purpose of this procedure is to provide instructions for the Cryogenic Target Watch in order to ensure a safe response to an emergency involving a LH_2 target.

2. Responsibilities

The Cryogenic Target Watch is responsible to respond to and investigate any alarm involving a liquid hydrogen target.

3 Prerequisites

3.1 The alarm is diagnosed to be caused by a hazardous condition:

3.1.1. "High Gas" and "Vacuum" alarm occurring simultaneously.

3.1.2. The target fire wire alarm is activated

3.2 Trained and qualified Cryogenic Target Watch.

4. Precautions

Liquid hydrogen information:

4.1 Hydrogen is combustible over a wide range of mixtures with oxygen air. In air at atmospheric pressure, the explosive limits are from 4% to 75% H_2 by volume. It is a colorless, odorless fluid, of low density (approximately 0.005 lbs./cu. ft. at NTP), and low viscosity. It diffuses rapidly. It has an extremely low boiling point (20°K) and liquid hydrogen will freeze any gas (except helium) which is allowed to mix with it.

4.2 A hydrogen ignition is probable when air or oxygen in proper mixture is present together with a source of ignition. Since the energy requirement is extremely low (order of a millijoule release at a point), and the mode of release is immaterial (any source such as a flame, static spark, or corona discharge will ignite H_2-O_2 mixtures provided that temperature of source is high enough), the possible source is extremely difficult to predict and/or control. Therefore, every possible effort should be made to prevent the occurrence of H_2-O_2 mixtures.

4.3 Hydrogen is not toxic, but will act as an asphyxiant if it dilutes the O_2 content in the atmosphere.

5 Procedure

5.1 In the event of "High Gas" and "Vacuum" alarm occurring simultaneously, the building should be immediately evacuated and the system "Crash Button" initiated.

5.2 If the target fire wire alarm is activated, the building should be immediately evacuated and the system "Crash Button" initiated.

5.3 The Cryogenic Target Watch should remain at the incident scene as long as there is no imminent threat to health or life. If the hazard becomes too great, then he/she shall withdraw and report to AGS Main Control.

5.4 The incident should be immediately reported to the Watch Supervisor and AGS Main Control, where the decision will be made to institute the Local Emergency Plan.

5.5 All other alarms should be investigated by the Cryogenic Target Watch, who will take corrective measures at the appropriate time. If the condition is not correctable, he/she would determine if the fault is hazardous to personnel or property and inform the Watch Supervisor of the situation; further measures would then be determined.

6 Documentation

Log Book entries are made hourly in the appropriate log for each cryogenic target.

7 References

7.1 Cryogenic Target Group Training and Operating Manual.

7.2 AGS Local Emergency Plan.

8. Attachments

Precautions and Safe Practices for Handling Liquid Hydrogen.

PRECAUTIONS AND SAFE PRACTICES

for handling

LIQUID HYDROGEN

UNION CARBIDE

LINDE COMPANY
DIVISION OF UNION CARBIDE CORPORATION
General Office: New York Offices in Principal Cities

FIRST AID NOTICE

FOR COLD-LIQUID BURNS

If liquid hydrogen contacts the skin or eyes, immediately flood that area with large quantities of unheated water and then apply cold compresses. If the skin is blistered or there is any chance that the eyes have been affected, get the patient immediately to a physician for treatment.

FOREWORD

Handling liquid hydrogen safely is largely a matter of knowing its properties and using common-sense procedures based on that knowledge. There are a number of precautions which should be observed because of the extremely low temperature of liquid hydrogen and its extremely high rate of conversion into gas. Hydrogen shares these properties with the other liquefied gases.

Although the purpose of this booklet is to outline the basic techniques for the safe handling of liquid hydrogen, the liquid is invariably accompanied by a certain amount of hydrogen gas. Since gaseous hydrogen is flammable over a wide range of concentrations in air, much of the material presented here has to do with handling the gas safely.

The user of liquid hydrogen should be thoroughly familiar, both with the precautions outlined in the following pages, and with the instructions accompanying any equipment to be used with the liquid.

GENERAL PROPERTIES OF HYDROGEN

Production

Hydrogen is produced commercially as a gas by several methods. Liquid hydrogen is produced by liquefaction of very pure hydrogen gas, using various ultra-low-temperature refrigeration techniques..

Properties of Gaseous Hydrogen

Hydrogen exists as a gas at atmospheric temperatures and pressures. It is colorless, odorless, and tasteless. It is the lightest of all elements and diffuses rapidly through porous materials and through some metals at red heat. The thermal conductivity of hydrogen gas at atmospheric temperature and pressure is about seven times greater than for air. Hydrogen is a flammable gas. It burns in air with a pale blue, almost invisible flame. When mixed in the proper proportions with air, oxygen, or other oxidizers, it forms an explosive mixture. It is non-toxic, but can cause asphyxiation by exclusion of air in confined areas.

Uses as a Gas

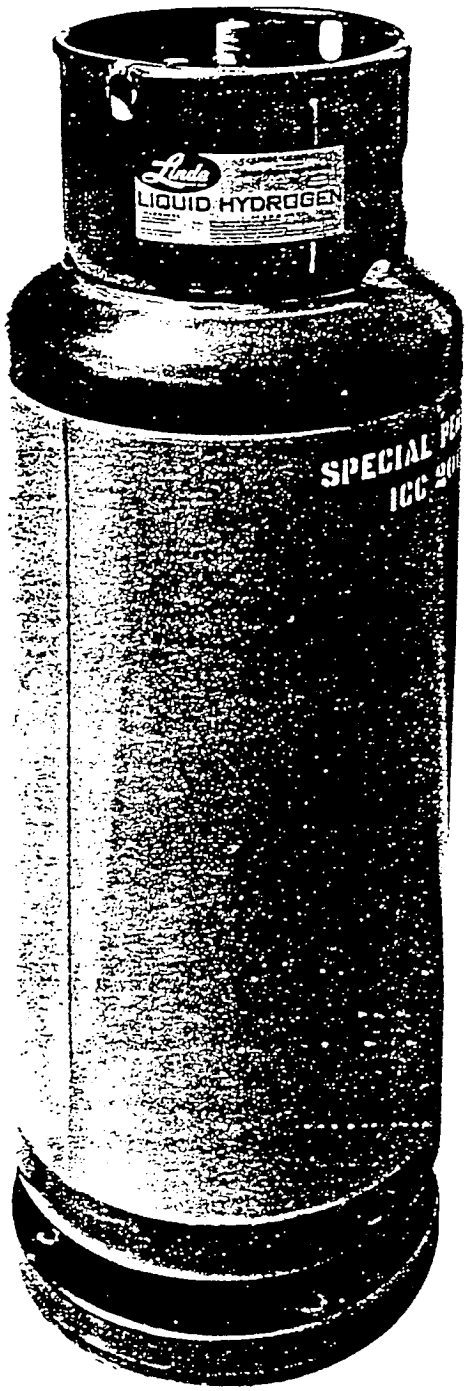
Hydrogen is used in the synthesis of ammonia and methanol, and in production of edible oils and various alcohols. It is also used to provide a reducing atmosphere in annealing, furnace brazing, and the production of sintered metal parts. Mixtures of hydrogen and argon are used extensively in cutting metal with Linde's HELIARC Cutting Process.

Properties of Liquid Hydrogen

Liquid hydrogen is transparent and odorless. Its density is about one fourteenth that of water. It is not corrosive or significantly reactive. The low temperature of liquid hydrogen can solidify any gas except helium. Liquid hydrogen has a relatively high coefficient of thermal expansion, which must be taken into consideration in the design of equipment for handling the liquid.

Uses as a Liquid

Because of its extremely low temperature, liquid hydrogen is being used increasingly in laboratory work for investigating the physical properties of matter at ultra-low temperatures. Typical applications include the study of cryogenic chemistry, super-conductivity, and the use of liquid hydrogen as a detector or moderator of high-energy beams. Liquid hydrogen is also assuming increasing importance as a fuel for rocket engines.



The LINDE LSH-150 Liquid Hydrogen Container

Specific Properties of Hydrogen

Atomic Weight	1.0080
Molecular Weight	2.0160
Molecular Symbol	H_2
Boiling Point at One Atmosphere, °F.	−423.2
Freezing Point, °F.	−434.6
Density of Liquid at Boiling Point, pounds/cubic foot	4.42
Density of Vapor at Boiling Point, pounds/cubic foot	0.084
Density of Gas at 70°F. and 14.7 psia. (NTP), pounds/cubic foot	0.005203
Density of Gas at 32°F. and 14.7 psia. (STP), pounds/cubic foot	0.00561
Heat of Vaporization at Boiling Point, B.t.u./pound	193
Specific Heat, at 70°F and 14.7 psia, B.t.u./pound-°F	3.418
Specific Heat Ratio, Cp/Cv, at 70°F and 14.7 psia	1.41
Volume Expansion of Liquid at Boiling Point to Gas at 70°F. and 14.7 psia.	839.9 to 1
Volume Expansion of Liquid at Boiling Point to Gas at 32°F. and 14.7 psia.	779.0 to 1
Critical Temperature, °F.	−400.3
Critical Pressure, psig.	173
Thermal Conductivity at One Atmosphere and 70°F, Btu-ft./sq.ft.-hr.-°F	0.106
① Coefficient of Thermal Expansion of Liquid	0.00798/°F
② Flammable Limits in Air, per cent by volume — *Lower:*	4.0
② Flammable Limits in Air, per cent by volume — *Upper:*	75.0
③ Flammable Limits in Dry Oxygen, per cent by volume — *Lower:*	4.0
③ Flammable Limits in Dry Oxygen, per cent by volume — *Upper:*	96.0
Ignition Temperature at Atmospheric Pressure, °F. — *In Air:*	1060 to 1085
Ignition Temperature at Atmospheric Pressure, °F. — *In Oxygen:*	1040
Heat of Combustion (Gross), B.t.u./cubic foot	325
Heat of Combustion (Net), B.t.u./cubic foot	275

① *Between freezing point and boiling point at one atmosphere.*

② *Water vapor (up to saturation) and pressure up to 200 atmospheres do not affect limits. Temperatures up to 400°C. do not change lower limit. However, at 400°C. upper limit is 81.5 per cent.*

③ *Pressure and temperature variations have only slight effect.*

Conversion Table

Liquid (at Boiling Point):

1 pound = 1.712 gallons = 6.481 liters
1 gallon = 3.785 liters = 0.5841 pounds
1 liter = 0.2642 gallons = 0.1543 pounds

Liquid (at Boiling Point) to Gas (at NTP):

1 pound = 192.3 cubic feet
1 gallon = 112.3 cubic feet
1 liter = 29.67 cubic feet

GENERAL SAFETY PRECAUTIONS

The potential hazards in handling liquid hydrogen stem mainly from three important properties: (1) the liquid is extremely cold (2) very small amounts of liquid are converted into large amounts of gas and (3) the issuing gas is highly flammable.

A. Handling the Liquid

1. Do Not Expose Liquid Hydrogen to the Air

The low temperature of liquid hydrogen can solidify any gas except helium. The solidified gases could plug restricted areas, such as valves or small openings, and cause a pressure failure. If air or oxygen is allowed to condense and solidify in liquid hydrogen, a potential explosion hazard can result. Because air (oxygen) will condense into it, liquid hydrogen, unlike other cryogenic materials such as liquid nitrogen or oxygen, should generally be handled in closed systems. An exception may be made where, with proper precautions, quantities of a few liters of liquid hydrogen are handled in laboratory or test operations in open Dewar vessels properly stoppered and vented as described in Section B-1. Most liquid hydrogen containers are entirely closed and provided with safety relief devices which exclude air and prevent oxygen contamination. The openings in liquid-hydrogen containers should be examined periodically to make sure that they do not become plugged with moisture frozen from the air.

2. Be Sure You Have Proper Ventilation in Work and Storage Areas

Always store and handle liquid hydrogen in well ventilated areas, whether indoors or outdoors, to prevent the accumulation of flammable concentrations of hydrogen gas. Large quantities of liquid hydrogen should be stored outdoors. Indoors, liquid hydrogen should be handled and used in well ventilated buildings, rooms, or hoods suitable for handling flammable gases. Containers of liquid hydrogen should be removed to the storage location when not in use.

If it becomes necessary to dispose of liquid hydrogen, dispose of it outdoors in well ventilated areas away from sources of ignition. Never dispose of liquid hydrogen in unventilated confined enclosures. Hydrogen gas evolving from the liquid may reduce the oxygen content below 16% by volume to cause asphyxiation of personnel. A person can become unconscious without sensing any warning symptoms such as dizziness. It should be noted that the lower flammable limit of hydrogen in air will be reached well before this condition is achieved.

First-Aid Notice

If a person becomes groggy or loses consciousness while working with liquid hydrogen, get him to a well-ventilated area. If breathing has stopped, apply artificial respiration. Whenever a person loses consciousness, summon a physician immediately. Keep all sources of ignition away from the overcome person.

Keep in mind that hydrogen buildup is most likely to occur when a room is closed, overnight for example. If you have any doubt about the amount of hydrogen in a room, ventilate the room completely before entering it.

3. Prevent All Fire and Explosion Hazards

Do not permit smoking, open flames, or any unapproved electrical equipment capable of causing a spark in any area where liquid hydrogen is stored, handled, or used. All equipment used to transfer liquid hydrogen should be grounded to prevent electrostatic sparks, which might ignite an explosive mixture of hydrogen and air. Use non-sparking tools in hydrogen areas.

4. Avoid Contact

Always handle liquid hydrogen carefully. At its extremely low temperature it can produce an effect on the skin similar to a burn. The very cold gas issuing from the liquid can also produce these "burns". Delicate tissues, such as those of the eyes, can be damaged by an exposure to the cold gas which is too brief to affect the skin of the hands or face.

Boiling of liquid hydrogen and splashing always occur when charging a warm container or when inserting objects into the liquid. Always perform these operations SLOWLY to minimize boiling. Whenever you handle the liquid be sure there is a safety shower, hose, or a large open container of water nearby. Use the water to wash off any area of the body that is accidentally splashed with liquid.

Never allow any unprotected part of your body to touch uninsulated pipes or vessels containing liquid hydrogen; the extremely cold metal may stick fast and tear the flesh when you attempt to withdraw from it. Use non-sparking tongs to remove objects immersed in liquid, and handle the tongs and the object carefully. In addition to the hazard of burns or of skin sticking to cold materials, objects that are soft and pliable at

room temperatures usually become very hard and brittle at the temperature of liquid hydrogen and are very easily broken.

5. Wear Protective Clothing

Protect your eyes with a face shield or safety goggles (safety spectacles without side shields do not give adequate protection). Always wear gloves when handling anything that is, or may recently have been, in contact with liquid hydrogen. Asbestos gloves are recommended, but leather gloves may also be used. The gloves should fit loosely, so that they can be thrown off quickly if liquid should spill or splash into them. High top shoes and cuffless trousers worn outside the shoes are good practice in handling any cryogenic liquid.

B. Selecting and Using Equipment for Handling Liquid Hydrogen

1. Use Only Containers Approved for Liquid Hydrogen

Use containers specifically designed to hold liquid hydrogen or approved for liquid hydrogen service by the manufacturer. Such containers are made from materials which can withstand the rapid changes and extreme differences in temperature encountered in working with the liquid. They should, however, be filled as slowly as possible to minimize the thermal shocks which occur when any material is cooled.

Quantities of liquid hydrogen greater than 5 liters should always be handled in enclosed vessels equipped with suitable relief valves or vents. Smaller volumes of liquid hydrogen up to 5 liters may be handled in open-mouth Dewar vessels. Such vessels should be stoppered with as small an opening to the atmosphere as is consistent with the work to be done. All containers of liquid hydrogen should be vented or protected by a safety device which permits the escape of vapor but excludes entry of air. The vent should be checked at regular intervals to insure that it does not become plugged with ice. Inadequate vent capacity can result in excessive gas pressure which may damage or burst the container.

2. Prepare Containers Carefully Before Filling

Before the initial filling of a warm container with liquid hydrogen it should, if possible, be precooled with liquid nitrogen. (Consult the container manufacturer for maximum weight of liquid nitrogen which may be used.) Pre-cooling with liquid nitrogen will remove all of the air in the container. It will also minimize the flash-off when the container is filled with liquid hydrogen. It is most important however, that all of the liquid nitrogen used for pre-cooling be removed from the container before adding hydrogen. If liquid nitrogen is not readily available, the container may be purged with gaseous nitrogen to make sure that all air is removed. After thorough purging with nitrogen, hydrogen gas should be used to displace the nitrogen, so that no nitrogen will freeze in the container when liquid hydrogen is introduced. Only flash-off or vaporized gas from liquid hydrogen should be used and must be warmer than -300°F. The impurities contained in most cylinder hydrogen make it unsuitable for purging or pressurizing liquid-hydrogen containers.

For filling of containers previously used in liquid-hydrogen service, purging is not required if there is positive assurance that the container holds only uncontaminated hydrogen. If the container has become contaminated with air or other harmful impurities, the remaining liquid hydrogen should be drained from the container. The container should then be allowed to warm sufficiently to vaporize any collected impurities, and then purged with nitrogen gas. As with initial filling, the nitrogen purge gas should then be displaced with flash-off hydrogen gas warmer than -300°F.

3. Use Proper Transfer Equipment

Use transfer equipment which has been designed for liquid hydrogen service. Unlike most other liquefied gases, liquid hydrogen should not be poured from one container to another or transferred in an atmosphere of air. If this is done, oxygen from the air will condense into the liquid hydrogen, adulterating it and presenting a possible explosion hazard. Pressure withdrawal through an insulated tube is recommended. The liquid should be pressurized with very pure, dry, regulated hydrogen or helium only; not with air or nitrogen. Dewar flasks or other equipment made of glass are not recommended; the possibility of explosion makes breakage too hazardous to risk.

C. Installing and Maintaining the Equipment

1. Location, Installation and Operation of Equipment

Since hydrogen is a flammable gas with a low explosion limit and wide flammable range, care-

ful consideration must be given to the location of storage and use facilities for liquid hydrogen. The importance of this becomes obvious when it is noted that only 25 liters of liquid hydrogen can create an explosive mixture if evenly distributed in a room 43 feet by 43 feet by 10 feet (about 19,000 cubic feet).

Because different quantities of liquid hydrogen will be used for different applications, it is not possible to make specific recommendations which will cover all uses of liquid hydrogen. Among the problems which must be considered are the location and type of construction of storage and use points, the ventilation arrangements, the electrical equipment requirements, the distances separating hydrogen equipment from other objects, the rules governing personnel, and the choice of fire protection equipment. Decisions on all of these questions must be made by the user on the basis of the properties of liquid and gaseous hydrogen as they apply to the particular situation.

For uses requiring large quantities of liquid hydrogen, the following recommendations are made. Unusual operating conditions may require special safety precautions in addition to those mentioned here. For small-quantity uses some of these recommendations can be eliminated after careful consideration of the problems involved.

a) Comply with any local ordinances or regulations which may be applicable.
b) Large quantities of liquid hydrogen should be stored outdoors; in a well ventilated area.
c) Where substantial quantities of liquid hydrogen must be used indoors, this should be done only in a separate building or room suitable for handling flammable gases. Such a building or room should be of non-combustible construction and well ventilated with air intakes at floor level and power-driven exhaust ventilators at the highest ceiling level. Such ventilators must exhaust to areas located away from sources of ignition and combustible materials. It is recommended that separate buildings or rooms be constructed in accordance with NFPA Bulletin No. 68, "Guide for Explosion Venting"
d) Safety valves and other equipment vents should be piped to the outdoors above the roof and away from sources of ignition.
e) Electrical equipment in areas of large liquid hydrogen storage and use must be in conformance with Article 500 of the National Electrical Code.
f) Areas for liquid-hydrogen storage and use must be adequately guarded and posted to prevent access by unauthorized personnel and to prevent smoking and other flames within the area.
g) Liquid-hydrogen storage and use areas should be located as far as practicable from combustible exposures, personnel occupancies, and sources of ignition.
h) Because large quantities of gaseous hydrogen can be released if the liquid is accidentally spilled, stable racks or carriers should be used for moving containers.
i) It is advisable that only the quantity of liquid hydrogen which is necessary for an immediate project be brought into an enclosed area.
j) In certain cases the installation of a continuous hydrogen gas analyzer and alarm may be warranted to warn of the presence of hydrogen.
k) All equipment must be adequately grounded to prevent the accumulation of electrical charges.
l) The use of non-sparking tools is recommended.
m) Avoid hydrogen-air mixtures in equipment being put into or removed from hydrogen service. Before hydrogen is introduced into equipment containing air, it must first be purged with inert gas. Equipment being taken out of hydrogen service must also be purged with inert gas to displace the hydrogen before admitting air.
n) All equipment should be leak-tested with hydrogen at the normal operating pressure. Other gases are not recommended for a final test because hydrogen may leak out of a system which is gas tight with respect to air or other common gases.
o) Liquid hydrogen containers must not be overfilled because a small increase in the temperature of the liquid causes an unusually high increase in liquid volume. Normal "outage" is not sufficient, and care must be taken to prevent containers from becoming liquid-full. Proper filling will depend on the container characteristics; therefore, consult the container manufacturer for correct filling procedures.
p) Provide adequate fire protection equipment, properly located, to protect liquid-hydrogen areas.
q) Always handle and store portable liquid-hydrogen containers in an upright position.

In using and storing liquid hydrogen, precautionary measures should be based on normal evaporation losses. Because of its high vapor pressure, it is not practicable to store liquid hydrogen without some venting of the container; therefore, it must be realized that some gaseous

hydrogen will be released from liquid containers during normal operation. It must also be recognized that spillage of liquid will release large quantities of gaseous hydrogen. Additional measures are necessary to prevent such spillage but, if it does occur, careful choice of location, building construction, and equipment can prevent serious consequences.

2. Get Competent Advice

Never install equipment or piping for liquid hydrogen without consulting someone thoroughly experienced in low-temperature work. The materials used must possess certain physical properties to qualify them for use at these extremely low temperatures. Ordinary carbon steels, for example, lose their ductility and become extremely brittle when subjected to the low temperature of liquid hydrogen. Certain ferrous alloys and a number of non-ferrous metals, on the other hand, may be used safely. These low temperatures also give rise to unique insulation problems and considerations of expansion and contraction. Dealing with all of these problems, and installing the special relief devices and other equipment to be used, requires the advice of a fully experienced person

3. Follow Prescribed Maintenance Procedures

Always follow all of the procedures prescribed by the manufacturer for operating and maintaining equipment used with liquid hydrogen. Everyone who works with the liquid must be properly trained and supervised by someone with experience in this field.

4. Restrict Access to Storage Units

Make sure that only authorized personnel have access to liquid storage units. Even if the supplier retains custody of the storage unit, you should be thoroughly familiar with the operation of the equipment. You must know, especially, the positions of the valves and switches to be used when the unit must be shut down in case of an emergency.

D. Entering Large Liquid Hydrogen Storage Tanks

Before entering any large liquid hydrogen storage tank, be sure all pipes to the tank are blanked or positively closed off. The tank should then be purged and warmed with an inert gas and then with air. If a check with instruments shows that the atmosphere in the tank is normal air, it should be safe to enter. Unless all lines are blanked, check the atmosphere for hydrogen and oxygen content frequently with instruments during work. If, for any reason, the supply of fresh air in the tank is doubtful, use breathing apparatus with its own supply of oxygen or air. Whenever you enter a tank, always make sure that an observer is stationed outside to check on your reactions while working and that you are equipped with a lifeline.

E. Fighting Fires Involving Liquid Hydrogen

It is not possible to outline specific fire-fighting measures to cover all types of fires involving liquid hydrogen because such measures will depend upon the quantity of liquid hydrogen involved, the location of the fire with respect to adjacent areas and their occupants, and other factors. The following general procedures, however, are applicable to all fires involving liquid hydrogen:

1. Remove everyone not actively engaged in fighting the fire. Liquid Hydrogen exposed to the atmosphere will produce a cloud of moisture condensed from the air. The flammable-mixture zone may extend beyond this vapor cloud and therefore personnel should be evacuated to points well outside the area of visible moisture.

2. If at all possible, shut off the flow of liquid or gaseous hydrogen.

3. Use large quantities of water, preferably in the form of a spray, to cool adjacent exposures and to cool any burning material below the ignition point. Adequate sprinkler systems and fire hoses with stream-to-spray nozzles should be considered for areas where large quantities of liquid-hydrogen are handled.

4. Depending upon the circumstances it is not usually advisable to extinguish a hydrogen flame in confined areas if the hydrogen supply can not be shut off. The continued escape of unburned hydrogen can create an explosive mixture which may be ignited by other burning material or hot surfaces. Usually it is better to allow the hydrogen to burn in confined areas and keep adjacent objects cool with water rather than risk the possibility of an explosion.

5. If electrical equipment is involved in the fire, be sure the electrical supply is disconnected before using water for fire fighting or use carbon dioxide or dry chemical extinguishers.

Lithographed in U. S. A.